A LIGHT-EMITTING PANEL AND OPTICALLY EFFECTIVE FILM

The invention relates to the field of light panels with LEDs, i.e. of light emitters which are flat in sections, with a plurality of light emitting semiconductor diodes (LEDs) as light sources.

Such light panels which also have the advantage of customisation are known from the documents EP 1 055 256 and WO 03/023857 as well as from WO2004/102064.

With such light panels, it is the long-term stability under difficult conditions (temperature, humidity, effect of noxious substances) as well as the inexpensive manufacturability which are counted as being important requirements. Furthermore, for many applications there exists the need of adapting the relatively narrow-band emission spectrum of LEDs to the respective requirements. With the frequency conversion by way of fluorescent dyes, on the one hand one is to achieve an as high as possible efficiency and an a good as possible homogeneity on the other hand.

The provision of technical solutions for light panels under these aspects is the object of the invention.

According to a first aspect of the invention, a light-emitting panel is provided which comprises a plurality of unhoused LED-chips as well as a film which covers a plurality of LED-chips, in a manner which protects from environmental influences, and at least partly influences, for example frequency-converts, light emitted by these.

"Panel" is to be understood as an element which is flat at least in sections, which may be dimensionally stable or flexible, and contains a plurality of light-producing elements which are preferably arranged in a regular pattern. In the context of this document, the light-producing elements are always LED-chips, i.e. unhoused LEDs.

Optically effective films for the conversion of light colour and/or for filtering certain light colours are, as such, known in combination with electro-luminescent light sources such as LEDs or OLEDs. Examples which relate to OLEDs and/ or LEDs are to be found for example in the documents WO03021622, WO03020846, US6653778, JP11199781. Examples which relate exclusively to OLEDs are to be found in the documents TW474038, US2002113546, JP2001164245. Optically effective films in the context of lens arrays or likewise are known in combination with electro-luminescent light sources such as LEDs or OLEDs. With regard to this, the documents US6654175 and US2003150916 are two examples of many.

Against this state of the art, the invention distinguishes itself in that a (single) optically effective film covers a plurality of LED-chips, such that they are shielded from environmental influences - in particular against moisture. According to the first aspect of the invention, accordingly apart from the function "optically effective", the function "protection" is realised with a single, inexpensively manufacturable element: a film.

In none of the known examples an optically effective film is disclosed, which would also even be suitable only for carrying out a protective function against aggressive gases and fluids, as well as against water and water vapour, for the electro-luminescent light sources and their electrical connections, and for the applied dyes in the case of conversion or filtering of light. As a result, in none of these documents a film is disclosed which would have a long-term stability of the chemical, mechanical and optical properties of the film.

Long-term stability with regard to the chemical properties means that the protective functions mentioned above would be maintained over for example at least 50'000 operating hours - for example also at operating temperatures of up to 120°C. Long-term stability with respect to the mechanical properties means that no brittleness and no fracture formation occurs under weather conditions out in the open and under a changing mechanical load for at least 50'000 operating hours, also at operating temperatures of up to 120°C. Long-term stability with regard to the optical properties means that the film may have a transmission loss at the most of 20% in the range of visible light, for example after at least 20'000 operating hours, but even better only after 50'000 operating hours, also at temperatures of up to 120°C.

It has been found that for example two classes of materials are very suitable as materials for such films according to the invention: fluoropolymers and transparent silicones. These are very well known as materials on account of their mechanical properties, but have not been considered at all for optical applications (fluoro-polymers) or as films, until now. A further suitable material class is represented by polycarbonates. The transparent materials such as PMMA, PC,PE, PET which are mostly used in combination with LEDs and OLEDs however do not often meet the set demands, neither with regard to temperature stability nor with regard to long-term stability.

In addition to the mentioned or similar highly transparent, long-term-stable and temperature-stable materials, it is possible to use thin layers of highly transparent, temperature-stable materials with which for example the light transmission reduces with time in the visible range. It is possible to select the layer thickness of such a material such

that the reduction of the transmission only plays a secondary role. One example of such a material are PI-resists which have an excellent transparency which however reduces slightly with time, a high resistance to most chemicals and a very good thermal stability. The advantage of newly developed PI-resists lies in the fact that they may be deposited and cured in layer thicknesses between 1 and 10 μm with usual methods, have an extremely high refractive indices (1.65 to 1.9) in the cured condition and thus are predestined for producing micro-optical, refractive elements (Fresnel-like elements).

The mentioned materials may be well combined with soluble or highly viscous materials, they may be deposited onto a base film of the mentioned materials or other transparent materials by way of methods such as coating, doctoring, spraying etc., and may at least partly cure there. Amorphous fluoropolymers for example from the company Dupont under the tradename Teflon AF are obtainable as soluble material. This material is soluble in certain perfluorinated solvents (e.g. FC75 or FC40 of the company 3M) and in this condition may be deposited onto a suitable carrier in thin or thicker layers by way of methods such as doctoring, spraying, immersion etc.. It has an excellent transparency to visible light, and the long-term stability is just as excellent as other fluoropolymers.

The protection which the mentioned materials provide with regard to aggressive gases and fluids as well as from water and water vapour may yet be significantly improved by way of vapour-coating and sputtering with an inorganic protective layer such as SiO_x, SiN_xO_x or TiO_x. For this, inorganic protective layers of less than 100 nm thickness are required. Under circumstances, by way of such an additional protective layer manufactured in a thin-layer method, one may also create a sufficient stability of light-emitting panels according to the invention, if the film material is otherwise not so suitable for providing the protective function.

The stable protection of an LED-array over a long time may be ensured with at least one layer or with a combination of several layers of the discussed materials.

In the case that the optically effective film is a conversion film (i.e. serves for the conversion of the light emitted by the LEDs into secondary light with a different wavelength), the necessary conversion dye (also called phosphor), may itself be protected from chemical influences by the film. This may be ensured for example by way of a multi-layered construction of the film. In such a construction, the required dyes may be incorporated between at least two layers of the mentioned materials, so that an adequately thick layer of the protective material is present "above" and "below" the dye- or phosphor layer. Such a construction prevents a gradual degradation, as may occur with dyes located close to the film surface. A degradation of the dyes is practically completely prevented by

the additional coating of the two protective layers with an additive inorganic protective layer, thus for example with the mentioned SiO_x-, SiN_xO_x- or TiO_x-layer which are a few 0.1 μm thick.

Under certain circumstances, the protective film may also contain additional, transparent materials which become dull to a greater extent, if these have special, desirable properties such as high refractive indices. These are preferably present in such thin layers that their dulling does not endanger the long-term stability, especially by way of selecting the thickness of the thin layers between maximally 1 micrometer and maximally 20 micrometers and/or by way of selecting the thickness of the thin layers such that the arising absorption is smaller than 15%, preferably smaller than 10%.

The manufacture of a dye layer embedded between two layers may for example entail the two layers being laminated onto one another; and before the lamination, the surface of at least one of the films is coated with dye, and the dye may additionally be rolled into one of the layers. As a second possibility, a matrix with a (conversion-) dye (for example a mixture of dissolved Teflon AF and the necessary dye quantity) may be deposited and cured before the lamination of the two layers. This may be effected at temperatures between 200°C and 400°C, for example at temperatures between 250°C and 350°C. With a third possibility, the mixture of dissolved Teflon AF and the required dye quantity is replaced by a mixture of transparent silicone and the necessary dye quantity. In this case, the upper FEP-film is not laminated on, but only rolled on, since the silicon offers sufficient adhesion.

Multi-layered, optically effective protective films may also be manufactured, for example with a first dye layer which acts in a converting manner, and with a second dye layer (or filter layer) which acts as a filter. Alternatively, one may also apply conversion dyes which are not mixable with one another, in different layers.

The conversion dyes or filter dyes must not be present over the whole surface of the film. It is for example possible to use an individual dye which is only present in at least one zone of the protective film. The illuminated-through protective film may display any pattern of two colours in this manner. It is thus for example possible proceeding from green LEDs, for a conversion of the green light into white light to take place in zones, and thus the green-white pattern, for example of notice signs, may is produced.

It is of course also possible to arrange several different conversion- and/or filter dyes in different zones. This may be effected in a single layer with suitable methods such as doctoring or spraying with masks. It is however also possible to arrange different dyes

in different zones in separate layers. It is possible to produces colour patterns running into one another in the latter manner by way of the zones with different dyes at least partly superimposing on one another. The arrangement of different conversion- and filter dyes in different zones may be carried quite far with respect to the zones becoming smaller and smaller. Thus for example without further ado, it is possible to allocate a different colour to each individual LED or the LED-array, although for example blue LEDs are used thought.

One may however go even further. For example, with photolithographic methods, it is possible without further ado to produce a pixel pattern with different conversion- or filter dyes on an optically effective protective film which is rearward illuminated in a uniform manner with monochromatic light from an LED-array, with which the pixels are significantly smaller than those of an LED-illuminated zone, wherein the pixels of a different colour may of course be arranged in different layers. In this manner, mixed colours which are otherwise difficult to produce may be produced for the observer.

One possibility of producing the optical functions of the light-collimation, light-divergence or light deflection is by way of providing at least one of the outer surfaces and/or one of the inner surfaces of the protective film which may be present as the case may be, with flat, optically effective elements which act as lenses or prisms. Such flat optical elements are for example refractive elements which are resolved into annular or strip-like zones in a fresnel-like manner, or micro-optical diffractive elements. Both types of optical elements may for example be produced in fluoropolymers or in epoxy resin layers or in other plastics by way of embossing. Corresponding structures may for example be produced in the discussed silicones such that a silicon layer is deposited onto a carrier layer thus for example onto a fluoropolymer layer, an embossing tool is subsequently pressed into the silicone layer, and finally the silicone layer is at least partly cured.

Alternatively or supplementary to micro-optical elements produced by embossing in the context of fresnel-like lenses or prisms, the protective film may have structures for effecting a light deflection by way of deforming the film by way of deep-drawing for example, such that at least locally, for example shell-like zones in the context of surfaces of cylindrical lenses and/or rotationally symmetrical lenses are present, wherein these shell-like zones are filled at the rear with a suitable transparent optical material, for example with silicone. The protective film may comprise additional elements for the diffuse scattering of the light, for example micro-hollow-glass balls.

The two mentioned types of optical elements (refractive/diffractive) within the context of the manufacture, differ essentially by the depth and fineness of the structures to

be produced and thus by the manufacturing method for the necessary tools. Methods for the production of such structures are known.

It should however also be noted that the diffractive elements may basically be constructed in two different manners. The first type consists of a multitude of the finest of groove-like structures which for example are introduced by way of embossing into transparent (transmissive elements) or non-transparent (mirror elements) material. The dimension of these structures lie in the magnitude of a few micrometers down to the dimensions which are smaller than the wavelength of the applied light. The second type, with corresponding dimensions, consists of non-transparent lines which are deposited onto transparent material, for example by way of sputtering and subsequent photolithographic structuring of the metal.

In the case of the use of fresnel-like, refractive elements, as is known, the desired optical effect becomes greater with a given penetration depth and an increasing refractive index of the applied materials. This for example means that on incorporating such optical elements into the discussed fluoropolymers having a low refractive index between approx. 1.3 and 1.35, significantly deeper and/or more finely resolved structures must be produced than for example with the use of a silicon with a refractive index of up to 1.5. An even greater effect may be achieved by the use, as the case may be, of an additional layer of the already discussed PI-resist or of another similar material with a refractive index of 1.65 to 1.9.

Diffractive optical elements have an optical behaviour which is dependent on the wavelength of light. The discussed PI-resist suitable for micro-optical refractive elements has a refractive index which for example continuously reduces from blue towards red light, from 1.75 to 1.65. These two facts in combination lead to the fact that the optical formation of non-monochromatic, and thus also white light is at least not simple with correspondingly constructed elements. In order to circumvent this difficulty, in may be advantageous in a multi-ply film if the monochromatic light firstly runs through the collimation optics optimised to the corresponding wavelength and only then to run through the necessary colour conversion layers. Such a layered construction may be manufactured according to the above embodiments by lamination etc.

As the case may be, additionally to one of the constructions outlined above, one may use at least one diffusely scattering surface and/or a diffusely scattering layer for producing the optical functions of "light scattering". Such may be achieved by way of roughening one of the present, outer and/or inner surfaces of the outlined, optically effective protective film. Possible methods such as for example etching methods, sand

blasting, brushing etc. for this have been known for some time. Alternatively to this, one may also produce a diffusely scattering thin or thick layer, for example way of incorporating a multitude of small bodies scattering the light into a transparent silicone resin or into amorphous Teflon AF. Thereby, it is advantageous if these bodies absorb the light which is incident on them as little as possible, but only reflect it. Diffuse light distribution may be then achieved by a multitude of reflections, even if the individual reflection is not diffuse Scatter bodies which fulfil the requirement of an as low as possible absorption are for example micro hollow-glass balls which are obtainable on the market down to diameters of approx. 1 μm.

Proceeding from one of the outlined protective film constructions, a further possibility of producing the optical functions of light collimation, light divergence or light deflection may also be described. All outlined film constructions are deformable - at least up to 10% local extension, but mostly significantly greater. Such a deformation may be effected for example by way of deep-drawing. This fact may be used in order to locally deform the protective film at least at one location, such that shell-like zones in the context of surfaces of cylindrical lenses and/or rotationally symmetrical lenses and/or prisms arise. If these shell-like elements are filled from behind with transparent material, then this back-filling acts as a corresponding, refractive optical element.

Instead of the previously described manufacturing method by way of lamination or differently designed layering of various layers, one may also manufacture a conversion film or diffuser filling for example by way of extrusion of a mixture already containing the dye or diffusion body, or with another suitable method.

According to a particularly preferred embodiment, the film is held at a distance to the light-emitting surface of the LED chip by spacer elements, such that no heat bridge between the film and the chips exists. For example, spacer elements in the form of rods or webs of a non-metallic, thermally poorly conducting material, for example of plastic or in the form of a transparent layer may be attached between the film and a carrier element carrying and electrically contacting the chips. It may also be the case that the LED-chips are surrounded by pressure-resistant elements projecting beyond the LED-chip in height, with aperture-like or concave-mirror-like openings and that the film is deposited onto the common surface of these elements as an additional protective film. Instead of this, the film may also be fastened on spacer elements attached between the elements or on thermally insulating spacers attached on an upper side of the aperture-like or concave-mirror-like elements.

According to a first sub-aspect of the first aspect, the film is a conversion film or a diffuser film, i.e. it contains fluorescent dyes and/or diffusers. The fluorescent dye (here it is also called conversion dye) and/or the diffusers are embedded into a first layer construction. A second layer construction is arranged on the side of the first layer construction which faces the light-producing elements. The first and the second layer construction consist in each case of one or more layers. Preferably, all layers of the first layer construction and all layers of the second layer construction in each case have a similar refractive index, i.e. the refractive index differences between layers within the first or the second layer construction are small, for example maximal 0.1 or maximal 0.05. In contrast, there is a substantial difference between the refractive indices of the first layer construction and the layers of the second layer construction, wherein the refractive index of the layers of the first layer construction is small - for example smaller than 1.5, and the refractive index of the layers of the second layer construction is as large as possible - for example greater than 1.5. The transition between a boundary layer of the first layer construction and a boundary layer of the second layer construction if not flat but has boundary surfaces forming an angle to the plane of the layering, or possibly waved boundary surfaces. In a preferred embodiment, the transition in cross section forms a "zig-zag" structure, i.e. the boundary surfaces in an alternating manner form a negative and a positive angle to the plane of the layering. The angle need not be constant in its magnitude, but may possibly vary and for example also run in a saw-tooth manner in cross section.

The reason for this construction is the following: light emitted from a conversion dye or from a diffuser (in the following called "secondary light") is in principle not directed. On account of this, significant components of the secondary light are radiated back in the direction in which the light-producing elements are located (thus to the "rear") or radiated away laterally, and are lost. Due to the construction according to the invention, light irradiated away to the rear is refracted at an oblique boundary surface to the perpendicular. A more shallow angle to the layer construction results for a large part of the - statistically distributed - angle of incidence, so that a larger part of the light is reflected at a rear boundary surface of the second layer construction, thus distant to the first layer construction, and remains in the film. After a renewed refraction at the transition between the second and first layer construction, the light may be radiated to the front, thus being of use. If the film contains diffusers, the light may also again be scattered by diffusers.

The efficiency of this arrangement may yet be increased if also the surface, thus the transition between the layer construction and a surrounding medium, contains non-plane boundary surfaces. For example the course of this transition may follow the course of the transition between the first and the second layer construction, so that the thickness of the first layer construction is approximately constant as the function of the position in the layer

plane. "Approximately constant" for example means that the extension in the z-direction (i.e. the direction perpendicular to the plane of the layering) does not vary by more than one third of the average thickness. Embodiments with which the position in the z-direction of the transition between the first and the second layer construction and that of the transition between the first layer construction and the surrounding medium varies by a value which is at least 2/3 of the thickness of the first layer construction are particularly preferred. The light guiding effects within the first layer construction are then practically prevented.

As a whole, the construction according to the first sub-aspect thus entails an increase radiation efficiency with a given illumination power of the light-producing elements.

The concept of the first sub-aspect may also be used independently of the first aspect of the invention, for example by way of depositing the previously explained layer system with a first and second layer construction directly onto an OLED (organic light-emitting element). It may also be realised in a conversion film able to be used in any manner. Such a conversion film for example yet has a carrier film, onto which the layer system which under certain circumstances is not mechanically stable, is deposited. Instead of a conversion film, the layer system according to the invention may also be realised in a mechanically stiff conversion plate.

According to a second sub-aspect of the first aspect of the invention, it is a question of comparatively small spectral width of the emission spectra of light diodes and of the absorption spectra of conversion dyes as well as of the production of homogeneous outward radiation characteristics of the light-emitting panel.

For this, the panel with an array of electrically contacting LED-chips per LED-chip or unit with several LED-chips has a concave-mirror-like or aperture-like optical element by way of which the radiated electromagnetic radiation may be concentrated onto a comparatively small spatial angle about a radiation direction. Such optical elements are drawn in the international patent application PCT/CH2004/000263 (in particular in Fig. 3a-3h and their description) as well as in the Swiss patent applications 663/04 (Fig. 1b-1d) and 1425/04. The contents of these patent applications are expressly referred here, and their content is herewith is to taken up into the contents of this patent application. According to the second sub-aspect, the conversion film is arranged at a distance *d* to a carrier element carrying the LED-chips and the optical elements. The optical elements are formed and/or arranged such that sub-groups of several LED-chips or units of LED-chips are formed, whose radiated light is incident in the plane of the film - thus at the distance *d*.

This, in a first variant, permits the use of LED-chips with slightly different primary light wavelengths in each subgroup if the film is a conversion film. The sum of the emission spectra of the LED-chip may then be relatively broad. By way of this, it becomes possible for the produced secondary light to achieve constant radiation characteristics with regard to brightness and wavelength (colour). This is particularly advantageous when a constant optical impression is important.

According to a further variant, the film is a diffuser film and the LED-chips are RGB chips with a suitable mixture (i.e. chips with primary light emission in the colours red, green and blue, whose spectrum is supplemented into white light or to any coloured light). The design according to the invention succeeds in the panel appearing really as white to the observer, and not as a superposition of red, green and blue points on closer observation. This variant is particularly advantageous with constructions in the manner of a screen where the composition of red, green and blue light varies as a function of time in a sectorwise (or pixelwise) manner. It is likewise very suitable for panels with which the colour of the illumination changes as a whose or in large sectors. Such panels for example are applied in aircraft where the colour of the lighting may vary between white, blue, red.

In both variants, the conversion- or diffusion film may be supplemented by a mask layer which permits the entry or possible exit of light into or out of the film only at those locations in which the primary light beams cross. Edge effects may thus be blocked out.

The simultaneous application of both sub-aspects, i.e. the combination of the film with the first and second layer construction and the non-flat transition with the previously explained second aspect is particularly preferred - but not necessary.

According to the various embodiments of the first aspect, the film may be arranged such that no heat bridge to the LED-chips is present, and that the film therefore remains comparatively cool. This also permits the use of conversion dyes whose quantum efficiency greatly reduces already at temperatures around 50°C or with temperatures lying slightly above this. Thus significantly more conversion dyes are available in comparison the state of the art, amongst these also particularly efficient and/or particularly inexpensive inorganic dyes.

According to a second aspect of the invention, a panel with a carrier element and with a multitude of unhoused LED-chips are provided, wherein a covering is allocated to each LED-chip or each unit of a few LED-chips lying next to one another, said covering containing the conversion dye and lying directly on the LED-chip/the LED-chips or one or

more transparent protective layers surrounding these locally. The thickness of the complete covering is such that it follows the shape of the chips. The covering is manufactured for example in a thin film method. Preferably, the thickness is less than the thickness of the - often two-dimensional (surface-like) - LED chip, preferably at least by a factor 2, for example at least by a factor 4. It is for example at the most 10 μm, for example maximal 5 μm or maximal 2μm. This is significantly less that the feasible minimal chip thickness today of 50 to 100 μm. As an alternative criterion, one may stipulate that the volume of layer containing the dye per LED and associated pad for a wire bond exceeds the volume of the LED-chip at the most by little, for example at the most by a factor of 2, or not at all.

The deposited layer containing conversion dye distributed in a homogeneous manner or in a layer, is preferably deposited so thinly that - as the case may be after curing - it is so thin, that it homogeneously follows the shape of the chip. This means that the thickness of the layer measured in a light emission direction varies by no more than 30%, preferably no more than 20%, particularly preferably no more than 10% beyond the chip. In this case, it is ensured that each beam of short-waved light (UV-radiation according to the definition used in this text is also indicated as "light") exiting the chip sees the same quantity of dye and thus one avoids different colours at different exit locations. This is particularly advantageous with certain newer obtainable chips which on account of their shape, for example on account of obliquely directed side surfaces, ensure a significantly increased light exiting efficiency. With newer chips which are offered by the company Cree, for example more than 70% of the light exits at the oblique side surfaces. The layer for conversion - it serves generally for the conversion of the short-waved light radiated from the LED-chip towards a larger wavelength - thus preferably covers all open sides of the LED-chip as uniformly as possible.

For series production, the covering of the chips of a panel is deposited in a batch process, for example in a vacuum by way of a mask, such that defined zones arise, in which in each case a chip and possibly a contact pad/contact pads is/are embedded by these contacting wire bonds.

The covering, apart from the at least partial frequency conversion of the electromagnetic radiation produced by the chips, also fulfils a protective function.

The following methods are to be considered as techniques for depositing the layer - with or without mask:

Spaying:

The conversion dyes may be mixed with a suitable optically transparent carrier material such that they are firstly contained in the carrier material in a sufficient concentration, and that secondly the mixture in its viscosity, is manufactured such that it may be sprayed on in thin layers. Since it is particularly the organic dyes which have a constantly improving life duration, the better protected they are from water, water vapour and oxygen, advantageously optically transparent silicones or amorphous fluoropolymers such as Teflon AF of the company Dupont are applied. With the use of powder-like inorganic dyes, this mixing is effected by way of mixing into the substrate material, with a solvent as the case may be (also called matrix material in the following). As a rule, thereby the dye grains have diameter of significantly more than one micrometer. It is however also possible to mix in nano-structured, inorganic dyes whose grain size is smaller than the light wavelength. With non-structured dyes, there is no light scattering at the dye grains. Methods for the economical manufacture of such nano-structured dyes are being developed worldwide at many locations. The same procedure is of course in principle conceivable with the use of organic dyes which are mostly also supplied in powdered form. Organic dyes may however, with full effectiveness and in a very low concentration, i.e. in a few percent by volume and less, be dissolved in suitable solvents and be mixed with the carrier material in this form. This may be effected in a particularly efficient manner if the substrate material may be diluted with the same solvents. Many organic dyes and many suitable silicones may for example be dissolved in toluol. One may produce a homogeneous mixture in this manner with which, after driving out the solvent, the optically transparent carrier material contains the dye such that no scattering of the dye is effected. Generally, the use of dissolved organic dyes is particularly preferred, since no scattering is effected. The sprayed mixture typically contains at the most a few percent of dye, often less than 1 % or even less than 0.1%.

A spraying process may be implemented such that the complete surface of the LED-array may be coated quasi simultaneously with a thin layer of the sprayed material in one working procedure. In particular, it is also possible to implement the spraying process such that not only the plane surfaces but also the inclined or approximately perpendicular side surfaces of the LED-chip are coated.

Thin-layer method:

According to a second possibility, the conversion dyes may also be deposited with a so-called thin-layer method such as vapour deposition or sputtering, or all their further developments and variations, such as for example chemical vapour deposition (CVD), physical vapour deposition (PV), in each case including sub-type such as laser-CVD etc.,

plasma coating, laser coating etc.. All these methods are summarised under the term vacuum coating in the following embodiments for the sake of simplicity.

This method is characterised in that the dyes may be deposited in very thin layers such that such that they cover the LED-chip uniformly at all open surfaces. Thereby, the density of the arising layer may be controlled such that the light emitted from the LED-chip is accommodated and converted completely or only with regard a defined part.

The layer thicknesses of that being discussed, as a rule, are only a few nm up to a few 100 nm, for example up to maximally 500 nm.

Since it is particularly the organic dyes which have an even better life-duration, the better they are protected from water, water vapour and oxygen, it is advantageous if a corresponding protective layer arises in the course of the vacuum coating - and possibly without breaking the vacuum.

This is possible by way of implementing the vacuum coating process such that at least two different materials are coated simultaneously and one after the other. The one material is then the conversion dye or a conversion dye mixture, whilst the other material is an optically transparent protective material such as for example SiO_x or SiO_xN_x. The optically transparent protective material is present directly on the dye layer, but rather below and above the dye layer and even better also mixed with the dye of a layer. The process may then take its course for example such that firstly as the case may be, an SiO_x or SiO_xN_x layer of a few 10 nm thickness is produced. After this follows a layer of a few 10 nm thickness in which conversion dyes and SiO_x or SiO_xN_x are present in a suitable mixture, and finally, once again an SiO_x or SiO_xN_x layer of a few nm thickness may follow. In this manner, an organic dye may be incorporated completely into protective material and this be protected in an optimal manner.

The terms "at the bottom" and "at the top" or "below" and "above" in this text are generally related to the radiation direction, i.e. "above" is that direction in which light is radiated, whilst "at the bottom" indicates the rear side of the light source, thus of the light panel, seen from the LED-chips.

Such a layer or layer sequence with a protective material such as SiO_x or SiO_xN_x has the further advantage that of course not only the organic dyes but also all components lying behind it, thus in particular the LED-chip and its electrical connections are optimally protected from chemical environmental influences, so that one may once again reckon with an even more improved life duration of the complete LED-array.

According to a first sub-aspect of the second aspect, the conversion covering - for example with the aid of a mask - is deposited onto the panel with chips which are already electrically contacted (bonded). The chip and also the electronic contacts are then completely protected from oxygen and passivated. If the deposition of the conversion covering is effected in a vacuum, then all vacuum processes may proceed without disturbing the vacuum.

According to a second sub-aspect of the second aspect, a conversion covering is deposited onto the panel which comprises chips which are not yet electrically contacted or only electrically contacted on their lower side (fastened by the "the bonding"). Then the electrical contacts for the second electrical contacting - thus the "pads" as well as a contact surface on the front side of the chips - with the provision of the conversion covering, must be left free. A subsequent contacting may for example be effected by way of a transparent electrically conductive material which in an two-dimensional manner is deposited locally onto the vicinity of the chip, or by way of a metallic material forming a narrow strip running radially on the chip. This on the one hand spares a wire bond and on the other hand permits the potential of saving space. A contact pad may be designed as a narrow strip surrounding the chip and does not need to be present as a relatively large surface formed next to the chip. This permits an increase in the packing density, at least in embodiment forms in which this is not limited by the removal of heat.

In this and in other cases, it is necessary for ensuring the functioning ability of the finished LED-array, for the arising colour conversion layer to be present only at defined locations of the LED-array. It may for example also be useful if the colour conversion layer at certain other locations of the carrier is "misused" to give rise to a locally passivated location, for example in the context of a solder stop.

Such a structured colour conversion layer may be produced by way of the process of deposition being effected by way of a so-called shadow mask which only permits access to the coated regions. Such a process is easy to master since the accuracy with which such a mask must be manufactured and deposited lies in the range of ± 0.1 mm. A shadow mask may - with a correspondingly somewhat reduced accuracy - also be applied with the spraying process described above.

"Fluorescent dyes" or "phosphors" in this text are always meant as dyes which absorb the electromagnetic radiation of a first wavelength and thereupon emit electromagnetic radiation of a second wavelength different therefrom. Phosphorescing

dyes - i.e. dyes of the mentioned type with which a certain time passes between the absorption and the emission - are expressly included by this.

Organic or inorganic dyes are known as such fluorescent dyes. Such inorganic dyes exist in large numbers. Known examples are $Y_3AL_5O_{12}$:Ce, ZnS:Cu:Mn, ZnS:Cu or $SrGa_2S_4$: Eu2+ etc. Such organics dyes, also known as laser dyes, are available in an almost unlimited selection. Examples are dyes known under the trade name Lumogen of the company BASF, Yellow 172 of the company Neeliglow, Inida and laser dyes such as Courmarin 6, Courmarin 7, Fluorol tGA, DCM, Pyridinge 1, Pyrromethene 546, Uranine and Rhodamine 110 which are available form numerous dealers.

Embodiments of the invention are hereinafter described in more detail by way of drawings. In the drawings, there are shown in

Fig. 1	a cross section through a film for a light panel according to the first sub-aspect of the first aspect of the invention,
Fig. 1a	a view of a possible course of the transition between the first and the second layer construction in a film according to Fig. 1,
Fig. 1b	a schematic cross section through a light panel according to the first aspect of the invention,
Fig. 2	a schematic cross section through a cut-out of a light panel according to the second sub-aspect of the first aspect of the invention,
Fig. 3	a qualitative representation of the superposition of the emission spectra of several different LED-chips and for comparison, an absorption spectrum of a conversion dye,
Fig. 4 and Fig. 4a	a cross section through the principle, in each case of a reflex OLED film,
Fig. 5	a cut-out of a light panel according to the second aspect of the invention, in cross section,
Fig. 6 and 6a	in each case, a cut-out of a further light panel according to the second aspect of the invention.

Figures 7a
to 7e show the schematised, cross sections, not to scale, of different embodiments of protective films with a single-ply colour- or phosphor layer for light conversion or light filtering of a light-emitting panel according to a first aspect.

Figures 8a
to 8d show the schematic cross sections, not to scale, of various embodiments of protective films with different colour- and phosphor layers arranged in a multi-ply manner, for light conversion and/or light filtering.

In Figures 9a
to 9d the schematic, cross sections, not to scale, of different embodiments of protective films with different colour- or phosphor layers arranged in a single-ply or multi-ply manner in zones, or in a pixelwise manner, for light conversion and/or light filtering, are represented.

Fig. 10 shows the schematic, cross section, not to scale, of a protective film with colour- or phosphor layers for light conversion or light filtering, and an additional layer for diffuse light scattering.

The film 10 drawn in **Figure 1** serves to convert electromagnetic radiation (light, UV-light) emitted by light-emitting elements at least partly into light of a longer wavelength. In the selected representation, primary radiation from below is incident onto the film and is radiated away to the top ("to the front") as secondary radiation. The film has a first layer construction consisting of a first protective layer 11, of a conversion layer 12, i.e. a layer which is transparent per se with at least one conversion dye, and of a second protective layer 13. A second layer construction is present on that side of the first layer construction which faces the light-emitting elements, and in the shown example consists of a single layer, specifically of the reflection layer 15. The transition between the second protective layer 13 and the reflection layer 15 is not flat, but consists of surfaces which are oblique, i.e. forming an angle to the plane of the layering - thus to the horizontal. The surfaces may for example, as is sketched in **Figure 1a**, run such that in each case four part surfaces (left drawing) or six part surfaces (right drawing) run into a tip 13.1 in the manner of a pyramid. The drawn pyramid shape is however not compelling; and also unequal surfaces may for example also be present, or another shape may be selected. It is only important for the majority of the boundary surfaces forming the transition to form an angle

to the plane of the layering. This under certain circumstances may also be achieved by a waviness of the transition.

The angle of the boundary surfaces to the plane of layering - thus in the drawn arrangement, the angle between the boundary surface normal and the vertical - is between 10° and 60°, preferably at least 12° and at the most 45°.

Particularly good results may be achieved if apart from the transition between the first and the second layer construction, also the transition between the first layer construction and the surrounding medium - generally air - thus the outer surface of the film, has boundary surfaces which form an angle to the horizontal. Preferably, the angle of these boundary surfaces to the plane of layering is between 12° and 45°.

The courses of the two mentioned transitions may in principle be independent of one another. According to a preferred embodiment, the boundary surfaces are however designed such that the variation of the position of the transition between the first and the second layer construction - thus the pyramid height corresponding quasi to the "deflection" in the z-direction - is at least 2/3 of the thickness of the first layer construction. The deflection may for example correspond to the magnitude of the thickness of the first layer construction. The course of the boundary surfaces must then be correlated. Ideally, as shown in Figure 1, the surfaces follow one another, so that the z-extension of the first layer construction remains constant.

The lateral transport of light is completely prevented in this embodiment.

The layers of the first layer construction have an as small and approximately as equal as possible refractive index, for example n = 1.3. The conversion layer - with the exception of the conversion dye - may be a fluoropolymer such as for example a plastic obtainable under the trade name Teflon. Alternatively, the protective layers may also consist of materials which have a slightly higher refractive index, for example between 1.4 and 1.5. Thus glass or SiO_x are considered which are deposited by vapour deposition or sputtering. A further possible material is silicone which is sprayed on. The layers of the first layer construction must very generally have the following properties:

- optically high transparency in the wavelength region of 400 nm to 1'000 nm; in this region the transmsisivity would be at least 90% with a thickness of 100 μm,

- minimal outgassing at temperatures of up to 100°C, since otherwise bubbles could arise in manufacture or operation,

- the conversion layer must survive a lamination deposition or spray deposition and curing of the two protective layers without damage and without outgassing. In the case that the protective layers consist of Teflon, thus means up to 350°C for a few seconds with the lamination,

- the first and second protective layer should be water-proof and water-vapour-proof, and only permit a slight diffusion of molecular oxygen. Ideally they are thin in comparison to the layer containing the dye.

The reflection layer or the layer of the second layer construction, as the first and second protective layer, is/are transparent and has/have a high refractive index, for example $1.6<n$. The reflection layer for example may consist of polyimide (n=1.8) The reflection layer may be very thin, for example 10 μm or less and may therefore have a significantly worse transmissivity, for example a transmissivity of at least 90% with a thickness of 20 μm. The efficiency of the film is even better when the reflection layer has an even higher refractive index. Transparent materials with refractive indices of significantly above 2, for example GaP, GaN, SiC or the so-called HMO glasses (heavy metal oxide glasses) exist. These materials however are to some extent thin-layer materials (i.e. at present may only be deposited with the thin-layer method). Since the thickness of the reflection layer must compensate the "travel" of the conversion layer (i.e. the amplitude of the change of the z-position of the transition between the first and the second layer construction), this means a very small travel and therefore preferably a very thin conversion layer of up to less than 1 μm. Dyes suitable for this (nano-structured, or dissolved in the conversion layer) are to some extent already available or under development in laboratories.

The total layer thickness of the layers of the first layer construction is for example between 10 μm and 200 μm, preferably less than 100μm. The thickness of the reflection layer varies in the drawn embodiment as a function of the x- and y-position; it may also be between 10 μm and 200 μm. With small thicknesses of the complete film, the film is deposited onto a transparent carrier (for example 1 mm acrylic glass).

Differing from the embodiment form describe here, the second protective layer 13 may for example also have a high refractive index; it then belongs to the second layer construction.

Furthermore all layers should have a high long-term stability, i.e. should not turn yellow or display brittleness. The loss of transmissivity is for example maximal 10% after

an operational duration of 100'000 hours at 50°C. The materials neither become crumbly under the same conditions of an operational duration of 100'000 at 50°C.

The functioning manner of the conversion film is the following (cf. also the sketched beam path in Fig. 1): electromagnetic primary radiation entering from below, for example blue or ultraviolet light or also visible light of a different wavelength, coupled by the reflection layer, is incident on the dye in the conversion layer. Here, longer-waved light is emitted in all directions. A considerable part of the longer-waved secondary light radiated away to the rear (i.e. in the direction back to the light-producing elements) is refracted by the transition structure 12 in a manner such that the angle to the layer plane becomes shallower, and that a large part of the light is reflected at the lower boundary surface of the reflection layer - thus generally the boundary surface between the reflection layer and the air. This light is then refracted again at the transition into the first layer construction and thereby only reflected back to a low extent, since on account of the first refraction, it is incident onto the oblique surfaces in an approximately perpendicular manner. The light may propagate through the layers of the first layer construction in an uninhibited manner and on account of the small refractive index of the layers of the first layer construction and the oblique surfaces in the transmission region to the surrounding medium, is also radiated to the front to large percentage.

Model computations have shown that the percentage of light radiated away to the front of less than 25% (plane conversion film with a refractive index of approx. 1.5) may be increased to approx. 40-50%, according to the invention by way of using a first and a second layer construction with refractive indices of 1.3 or 1.8, and the transition between the first and the second layer construction consisting of boundary surfaces tilted with respect to the horizontal by approx. 20°-30°. The percentage may be increased to approx. 70% by way of composing the outer surface of the film of oblique pyramid surfaces as in Figure 1 (angle: optimally likewise between 20° and 30°).

In particular, the second protective layer is optional and may be omitted. The film 10 may comprise a diffuser layer instead of a conversion layer, i.e. diffusers are present in the corresponding layer instead of a dye. In this case, in contrast to the above description, the secondary light which is reflected back may not propagate to the outer side in an unhindered manner but may be scattered again by the diffusers, it thus again serves as primary light.

The whole film may be attached on a plane carrier layer - glass for example - with a good transmissivity.

One light panel according to the invention is represented schematically in **Figure 1b**. The panel has a carrier element 101 of a, for example electrically conductive material as well as a layer sequence 102 of electrically insulating and electrically conductive, structured layers. Electrically conductive, structured layers may for example form a certain pattern of strip conductors and contact pads. The structured, electrically conductive layers and possibly also the carrier element serve for the electrical contacting of the LED-chips 103, for which possibly also wire bonds 109 are yet required. The structuring of the conductive layers is not represented in the figure. The light panel has one or more base elements 104 mechanically connected to the carrier element, with aperture-like or concave-mirror-like openings 105. In the shown embodiment, the openings have a parabolic-mirror-like surface, which together with the aperture effect contributes to the light being radiated away directed to the front (to the top in the Figure). The already mentioned patent applications PCT/CH2004/000263, CH 663/04 and CH 1425/04 are referred to with regard to a possible construction of the carrier element and base elements.

A film 100 with conversion dye is either located directly on a surface of the base elements or is arranged at a distance *d* to the carrier element by way of spacer elements. The film drawn in Figure 1b in contrast to the film of Figure 1 is designed such that only the transition between the first and the second layer construction consists of oblique surfaces. Spacer elements are preferably highly thermally insulating (i.e. heat conductivity of less than 1.5 W/m, preferably smaller than 0.5 W/mK) and may be present on the base elements 104 in the form of small blocks, rods, webs or likewise (rods 106) or be supported directly on the carrier element or its coatings (webs 107). They may also be designed as a transparent layer 108 which coats the base elements.

It is also possible to fasten the film (+ carrier layer) in its entirety with a "frame" which it has in common with the LED-panel. Such a frame may also be open on several sides (up to on all sides), thus e.g. only consist of a limited number e.g. four "posts". Open to the side is advantageous since air may then circulate, and the thermal transport towards the film becomes even smaller.

The spacing, thermally insulating and therefore mostly also electrically insulating elements 106, 107, 106 may also be used in combination with conversion films which do not have the described structuring with the first and the second layer construction. What is important is then the thermal decoupling between a film embracing a multitude of LED-chips, and the LED-chips or their carrier, and, as the case may be, base elements. This, as already explained, permits the use of dyes whose efficiency rapidly reduces as a function of the temperature, already at temperatures of around 50°C.

On the other hand, the film according to Figure 1, may also be applied without the base elements represented in Figure 1b. The collimation effect which these base elements have is not absolutely necessary, but it increases the efficiency of coupling into the first layer construction. The light panel in **Figure 2** is for example likewise constructed according to the principle described in the Figure 1, 1a and 1b. It differs from the light panel of Fig. 1b in the following manners:

- the carrier element 23 is locally spatially bent into shells or - if it is not mechanically stiff - is attached on a support element which is locally shell-shaped. An overlapping of the light beams at a distance *d* to the carrier element results on account of this, wherein these light beams are emitted by the LED-chips 25 of a sub-group - such may for example consist of four to sixteen LED-chips - and collimated by the aperture-like or concave mirror-like elements 24. The distance *d* corresponds to the distance of the film to the actual panel base body 22. The complete carrier element may as a whole have a large number of shell-like sections arranged in a regular pattern, in each case with a sub-group of LED-chips.

- the conversion film 20 (or diffuser film) optionally on its rear side (i.e. the side facing the LED-chips) has an additional mask layer 21 which only lets through light where the actual light beams are directed. Possible edge effects are blocked out by way of this.

- the LED-chips emit in different wavelengths. This does not mean that necessarily each chip of a sub-group needs to have an individual wavelength, but that at least two chips of a sub-group have different emission wavelengths. Examples of a sub-group of nine chips are wavelengths of 455, 457.5, 460, 462.5, 465, 467.5, 470, 472,5 and 475 in the case that the film is a conversion film, or 3 red 2 green and 4 blue chips in the case that the film is a diffuser film.

The concave-mirror-like or aperture-like optical elements 24, differently to the shown embodiment, may also be coherent amongst one another, thus parts of a base element 14 of the type drawn in Fig. 1b on the right.

The advantage of this procedure in the case of several LED-chips emitting blue light is illustrated in **Figure 3**. Here, suggested, but realistic emission spectra 32 of nine LED-chips (fine unbroken lines) as well as their sum 31 (thick unbroken lines) in each case normalised, are drawn. The absorption spectrum 33 of a conversion dye is likewise shown. One may deduce from the representation that with a shifting of the central emission wavelength of an individual LED-chip - for example on account of temperature change,

ageing etc. - also for example by less than 5 nm, the percentage of absorbed light may change tremendously. By way of this - the colour of the light panel perceived by the observer may change in a marked manner and this is observed in practice. For example, the panel may be perceived as being green instead of white. With a spectral distribution according to the invention however, the absorption efficiency is insensitive to a shifting of the emission spectrum by a few nm. The maximum of the sum emission spectrum always lies in the vicinity of the absorption maximum with shifting of ± 5nm.

Figure 4 shows an organic light emitting element (OLED), which a conversion film according to the invention which has been laminated on. The actual light-producing part is represented in a simplified manner. It has a light-emitting layer 47 which is given as a layer of transparent material with a small refractive index (for example Teflon n=1.3). This layer is surrounded by a first, reflecting electrode 48 (for example of aluminium) and a second transparent electrode 46 (for example ITO). Laminated on this or fastened in another manner, is the reflection film with a second layer construction consisting of a reflection layer 45 and the first layer construction, consisting of the optional second protective layer 43, the conversion layer 42 and the first protective layer 41. The description of Figure 1 is referred to with regard to the possible materials, refractive indices as well as the geometry of the transition structure 44 and the manner of acting.

The efficiency of the OLED construction becomes significantly better if the light-emitting layer likewise has a "zig-zag" structure (i.e. has boundary surfaces which form an angle to the plane of the layering - see **Figure 4a**). For this reason, an intermediate space 148 arises between the reflection layer 144 (i.e. the second layer construction) which is plane at the lower (or rear-) side, and the electrodes and light-emitting layers. This intermediate space or these intermediate spaces 148 are then for example filled with air or with an insert gas. A planar ending of the reflection layer 144 to air increases the efficiency, and lateral transport of light in the light-emitting layer 146 of the OLED does not take place.

Figure 5 shows a cross section through a section of a light panel according to the second aspect of the invention. An unhoused LED-chip 52 is represented on a carrier element 51 represented in a simplified manner - it may be a metallic substrate provided with an insulating layer and a structured conductive layer, a flex conductor plate provided on both sides with a (partly structured) conductor layer - for example of kapton - or any other suitable substrate. In contrast to the simplified representation of the preceding figures, the LED-chip is drawn in a typical shape in which apart from a front emission surface 52.1, it also comprises lateral oblique emission surfaces 52.2. The percentage of light which is emitted by these lateral emission surfaces is substantial. The complete

construction including the wire bond 53 (for example gold wire, diameter 25 µm) is provided with a layer construction in a local manner - i.e. in a vicinity of the LED-chip 53. This layer construction consists of an optional first protective layer 54a, of a layer 54b containing the conversion dye, and a likewise optional second protective layer 54c. The thickness of the complete layer construction is such that it follows the shape of the chip, thus is not or not significantly thicker than this. The total thickness is for example smaller or equal to 2 µm. The first and the second protective layer for example each consist of SiO_x, the conversion layer of co-sputtered SiO_x and dye.

The complete panel is simultaneously provided with the layer constructions in a batch process for the series manufacture of the light panel according to the second aspect. For this, a mask is positioned such that defined zones arise, in which in each case a chip and as the case may be, the contact pad of the already attached wire bond is embedded. Subsequently as the case may be, the first protective layer, the conversion layer and as the case may be the second protective layer are sputtered on in turns. One may also apply a different vacuum coating method in place of a sputtering process. All processes may take their course without breaking the vacuum. Other manufacturing methods are conceivable instead of vacuum coating processes, for example by way of doctoring on through a mask.

According to one variant of the embodiment of Fig. 5 which is not drawn, the layered construction ("the conversion covering") with the layer 54b containing the conversion dye does not only coat in each case a vicinity of each LED-chip, but the complete panel or at least several part surfaces of the panel which comprise several LED-chips. The mask may be done away with on manufacture in this variant. Pads for the later contacting of the complete construction (i.e. for the connection of the panel or of part pieces thereof to an electrical voltage source) may thereby be either covered, or the conversion covering may be broken through at the suitable locations. The drawn variant with the locally limited covering makes sense for example if metallic reflectors are present in the proximity of each chip, which ensure a removal of heat. The coating of these reflectors with a conversion layer is then generally more likely to be undesirable.

Light panels according to the second aspect of the invention have the advantage that, including the conversion layer, they may be very thin and that a layered construction may be provided in a suitable batch process, which may assume a conversion function as well as a protective function.

A light panel according to the second sub-aspect of the second aspect of the invention is represented in **Figure 6** (lower drawing). The conversion covering - i.e. the layer construction of the optional first and second protective layers 64a, 64c and

conversion layer 64b - is however designed such that the front contact surface 62a of the chip 62 is free of it. The layer construction neither covers contact surfaces ("contact pads") of the carrier element 62 (i.e. of the substrate). For this, a transparent, electrically conductive layer 65 is present which locally covers the chip and its vicinity, and creates an electrical contact between the peripheral contact surfaces of the carrier element and the front contact surface 62a of the chip. This embodiment as already stated has the advantages that no wire bond is required and that there is the potential of increasing the packaging density.

A method for depositing the conversion covering may be designed as follows:

In a first step, the chips are positioned on the carrier element, whereupon the rear contact surface 62b of the chips is connected to an corresponding contact surface of the carrier element by way of a die-bond process. A first and a second mask 66 and 67 respectively are subsequently positioned such that only a vicinity of a chip is laid bare, but the front contact surface 62a of the chips and also the contact pads of the carrier element are covered. One representation of the two masks 66, 67 can be seen in the upper drawing of Figure 6. The second mask 67 has a shielding element 67b for covering the front contact surface, and this for example is held by way of a few radially running wires 67c. The shielding element 67b may lie on the chip since no wire bonds are present which could be damaged by the mask. The deposition of the layers of the conversion covering in a vacuum batch process such as for example sputtering, is effected as a third step The second mask 67 is then pivoted away, which lays bare the front contact surface of the chips and the contact pads. The coating by way of ITO or another transparent electrically conductive material follows subsequently. The vacuum is preferably not broken during the process.

The first mask 66 may be possibly omitted in the manufacturing process, specifically when all LED-chips (or all LED-chips of a part surface) are connected electrically in parallel. A further alternative is the contacting by way of a narrow metallic strip running radially in the region of the LED-chip.

The relative positional accuracy between each chip of a panel and each corresponding mask part, in the x- and y-direction (i.e. both directions in the carrier element plane) must in each case lie within ± 70 μm at the most. This may still be achieved for large panels. The front contact surface of the chips which is to be shadowed has a diameter for example of 120 μm. In order for the radially running wires not to cause undesired open paths in the conversion covering, this covering should have a minimal distance to the chip. The wires are therefore bent accordingly.

One embodiment according to the principle of Figure 6 is drawn in **Figure 6a**. The drawn section of a light panel 160 comprises an LED-chip 162 arranged on a substrate 161. This is provided with an electrically insulating, transparent protective layer 164a which may extend also onto a vicinity of the chip, with the help of a mask corresponding to the second mask of Fig. 6. A transparent electrically conducive layer 165 (for example ITO) which effects an electrical contact between the front chip contact surface 162a and a peripherally arranged contact pad is located on this protective layer. The transparent, electrically conducting layer 165 is structured for example with the help of a mask corresponding to the first mask of Fig. 6. A contacting via strip-like metallic elements, for example via aluminium strips may for example be effected alternatively to the transparent electrically conductive layer. The complete construction is provided with a layer system which is deposited on a carrier, specifically a carrier film 166a - here of amorphous Teflon. With regard to the layer system, in the embodiment, it is the case of the above described layer system with a second layer construction 166b (highly refractive reflection layer) and of a first layer construction 166c (conversion layer and optional protective layers of for example Teflon or SiO_x). The layer system is preferably deposited in a flat manner, i.e. it covers at least a part surface of the complete panel which contains a plurality of LED-chips.

The conversion film (consisting of the carrier film 166a and layer system) may then be manufactured in a large-surfaced manner and be hotly deposited onto the panel at a later stage, so that it conforms to the shape of the chip. This may be effected by way of a mould punch or with a gas with a slight overpressure. Best of all, the LED-panel is provided with the conversion film over the whole surface and the film is removed locally at a later stage where necessary, by way of etching, lasering or cutting and pulling off (or likewise).

The conversion film addresses the problem of light radiated back from the conversion dye as is also present with the embodiments of Fig. 5 and 6. One must prevent a large part of the secondary light being simply swallowed again by the chip. The conversion film of Figure 6a acts as the embodiment of Fig. 1 and under certain circumstances entails a great increase of the component of coupled-out secondary light. The conversion film with the low-refracting carrier film (n=1.3) has the small disadvantage that in comparison to n=1.5, less primary light is coupled out of the chip. Thanks to the oblique side surfaces of the chip however, this reduction is only 1% which is of course more than compensated by the advantageous effect of the conversion film. As a whole a significant increase of the efficiency results.

The conversion film - this only as an example - may be manufactured as follows:

A mould surface with pyramids (according to Fig. 1 and Fig. 1a or comparable) is used. Such do exist for example in the form of inisotropically etched silicon. This is coated with a thin layer which later permits a detachment of the film. The conversion layer or the first layer construction is then manufactured for example by co-sputtering. A filling of the structure with the reflection layer (i.e. the second layer construction) for example in the form of a resist of polyimide, or a sol-gel process for HMO-glass then follows. The carrier film of transparent Teflon is then laminated onto the plane surface which has arisen, and the mould is removed and may be used again under certain circumstances.

The layer sequence between the ITO-layer and the conversion layer which is exchanged in Figure 6a compared to Figure 6 may of course also be used with embodiments with which no layer system structured according to the invention with a first and second layer construction is used. The conversion film of Fig. 6a may also be used in the construction analogously to Fig. 5, wherein then the conversion film at locations of possibly present wire bonds may comprise corresponding recesses, so that the contacts are not damaged on depositing.

The possible construction of conversion films according to the first aspect of the invention is discussed in the following figures. The films according to the figures may, but need not be additionally designed with the drawn features according to the first sub-aspect and thus have structures which contain a first and a second layer construction, wherein boundary surfaces between the first and second layer construction form an angle to the plane of layering, or are waved. The films may also be used according to the second sub-aspect of the first aspect.

The schematic cross section of a two-ply protective film not to scale is shown in **Figure 7a**, wherein the first layer 211 in the surface region which is protected by the second layer 212 contains dye or phosphor 213 for the light conversion or for light filtering. The two layers 211 and 211 consist of a highly transparent, long-term stable, protective film, thus for example of FEP or PFA films of the company DuPont available on the market. The dye quantity 213 necessary for the desired conversion or filtering of a light colour is introduced into the film 211 on one side.

This incorporation may for example be effected such that the required dye 213 is scattered onto the film 211 heated beyond its glass-point (in our example thus approx. 300°C) and rolled in under a slight pressure.

The total thickness of the film 211 for example lies between approx. 50 to 200 μm, that of the layer containing the dye 213 for example between 20 to 100 μm.

The likewise heated, for example between 20 to 100 μm thick second film 212 is laminated on directly subsequent to this procedure.

An extremely inexpensively manufacturable protective film with an almost homogeneous transition from film 211 to film 212 which in its middle, protected on both sides, contains the desired dye 213 arises.

Under certain circumstances, one disadvantage of the construction according to Fig. 7a may be that it is difficult to maintain a large homogeneity of the dye distribution over the whole film surface.

The schematic cross section of a protective film which is illustrated in **Figure 7b** and is not to scale, overcomes this possible disadvantage.

This protective film too consists essentially of two layers 211 and 212 of a highly transparent, long-term stable, protective film, thus for example of FEP or PFA films of the company Dupont available on the market. The same may apply for transparent layers of the protective films of the embodiments described in the following. Apart from these film materials, other film materials, for example ones known per se may also be considered.

The dye 213 necessary for the colour conversion or colour filtering is mixed homogeneously into a suitable matrix material. The mixing process takes place independently and with a large accuracy. The matrix material 214 may for example consist of highly transparent, dissolved amorphous Teflon AF of the company Dupont or of a highly-transparent, highly viscous silicone.

In the case of the use of silicone as a matrix material, the two films 211 and 12 are prepared on one side, for example by way of etching or suitable plasma treatment, such that silicone adheres to it. Correspondingly pre-prepared films are directly obtainable from Dupont.

The manufacture of the construction according to Fig. 7b is effected for example in that the homogeneous mixture of dye 213 and matrix material 214 is deposited onto the film 211 with a suitable method such as doctoring, in a homogeneous thickness.

In the case of the use of dissolved Teflon as a matrix material, an expulsion of the solvent is then effected, which may be effected at temperatures of approx. 100 °C. Thereafter, the second film 212 may be laminated on at temperatures in the region of approx. 300°C.

In the case of the use of silicon as a matrix material, as the case may be, firstly a partial curing of the silicone may be effected. The second film 212 is then laminated on and the silicone is cured.

The thickness of the films 211 and 212 lie for example between approx. 20 to 200 μm, that of the matrix layer 214 containing the dye 213 for example between 20 to 100 μm.

Figure 7c shows a protective film construction according to Fig. 7b, whose protective function and long-tern stability are improved in that the complete film is coated at a later stage on both sides with an additional inorganic protective layer 215 a few 0.1 to 10 μm thick, for example of SiO_x or SiN_xO_x, with a suitable vacuum method such as sputtering or vaporisation for example. It would of course also be possible to also coat a film according to Fig. 7a. A mere one-sided coating with an inorganic protective layer is also possible.

The construction according to **Figure 7d** differs from that according to Fig. 7c in that the two layers of inorganic protective material 215 are located in the inside of the film in the direct vicinity of the matrix material 214 mixed with dye 213.

This has the advantage that for example the protective layers 215 do not become fractured with bending loads, or that this only occurs as significantly greater loads.

The manufacture of the protective film according to Fig. 7d is effected for example in that the two films 211 and 212 are provided at least in each case on one side with the inorganic layer 215 already before the later creation of the composite.

Figure 7e shows a construction according to Fig. 7c with which the two outer-lying inorganic protective layers 215 are protected from the formation of tears by two additional layers 216. The two additional protective layers 216 are for example likewise of FEP-film, wherein a thickness of 10 to 50 μm offers sufficient protection.

The schematic cross section, not to scale, of a multi-ply protective film is shown in **Figure 8a**, wherein a first layer 221 in the surface region protected by the second layer

222a contains dye or phosphor 223a for light conversion or light filtering. The second layer 222a again contains dye or phosphor 223b for light conversion or light filtering, in the surface region protected by the next layer 222b.

The constructions with several dye layers such as in Figure 8a but also in Fig. 8b, 8c, 8d also make sense for example if a stepwise colour conversion is to be effected - thus for example from ultraviolet to blue and then from blue to white and/or if for example excess, non-converted light is to be filtered out after the colour conversion.

The introduction of the dyes 123a and 123b as well as the joining-together of the films 121 with 222a and 122a with 122b is effected in a layered manner, as outlined in the construction according to Figure 7a.

It is also possible to manufacture constructions in the corresponding manner with yet more different layers of conversion- or filter dyes. One disadvantage of the construction according to Fig. 8a may under certain circumstances be the fact that it is difficult to maintain a large homogeneity of the distribution of the dyes 223a and 223b over the complete film surface. The schematic cross section of a multi-ply protective film which is not drawn to scale **in Figure 8b** alleviates this possible disadvantage.

This protective film too consists essentially of layers 221, 222a and 222b of a highly transparent and long-term stable protective film, thus for example FEP or PFA films of the company Dupont which are obtainable on the market. The dyes 223a and 223b which are necessary for the colour-conversion or colour filtering are mixed homogeneously into suitable matrix materials 224a and 224b. This mixing process takes place independently and for example with a large accuracy. The matrix materials 224a and 224b may for example consist of highly transparent, dissolved amorphous Teflon AF of the company Dupont, or of a highly transparent highly viscous silicone.

In the case of the use of silicone as a matrix material, the films 221, 222a and 222b are for example prepared on one side, by way of etching or suitable plasma treatment for example such that silicone adheres onto it. Correspondingly pre-prepared films are obtainable directly from Dupont.

The manufacture of the construction according to Fig. 8b is effected in a layered manner corresponding to the procedure outlined with respect to Fig. 8b. The thickness of the films 221, 222a and 222b for example lie between approx. 20 to 200 μm, that of the matrix layer 224a and 224b containing the dye 223a and 223b for example between 20 and 100 μm.

Figure 8c shows a protective film construction according to Fig. 8b, whose protective function and long-term stability is improved in that the complete film is coated at a later stage, with an additional inorganic protective layer 225 for example of SiO_x or SiN_xO_x, with a suitable vacuum method such as for example sputtering or vaporisation. It would of course also be possible to accordingly coat a film according to Fig. 8a.

The construction according to **Figure 8d** differs from that according to Fig. 8c in that the two layers of inorganic protective material 225 are located in the inside of the film in the direct vicinity of the matrix material 224a and 224b mixed with the dye 223a and 223b respectively.

This has the advantage that for example with bending loads, the protective layers 215 do not become cracked or that this occurs at significantly higher loading. The manufacture of the protective film according to Fig. 8d is effected for example in that the two films 221 and 222b are provided at least in each case on one side with the inorganic protective layer 225 already before the later creation of the composite.

Figure 9a shows a protective film which is constructed essentially according to Fig. 7b, which differs from the film according to Fig. 7b in that the mixture of the dye and the matrix material 223 is not present over the whole surface of the complete film, but only in zones. The intermediate spaces 234 between the zones 233 may, as the case may be, be filled out with the unmixed matrix material, or simply be hollow.

The deposition of the mixture 233 in zones and, as the case may be, of the unmixed matrix material into the intermediate spaces 234 may for example be effected in the manner of screen-printing thus by way of doctoring with suitable screens. A construction according to Fig. 9a is suitable for the production of a two-coloured picture of appearance of the protective film starting with monochromatic light.

Figure 9b differs from Fig. 9a in that the zones 233a and 233b contain different dyes. Of course further zones with further dyes may be present. A construction according to Fig. 9b is suitable for the production of a multi-coloured picture of appearance, starting with monochromatic light.

Figure 9c differs essentially from Fig. 9b in that the zones with different dyes 233a and 233b, similar as that shown in Fig. 8b, are arranged in different layers which as the case may be are separated by way of an intermediate film 232a. This firstly may have the

advantage with regard to manufacture that a very sharp transition from colour to colour may be produced. Secondly, the zones 233a and 233b - as shown in the left part of Fig. 9d - partly overlap, by which means one may produce additional colour effects.

The right part of Fig. 9d illustrates the possibility of arranging zones of mixtures 233a and 233b or zones with unmixed matrix material 234a and 234b in different layers in a pixel-like manner, such that several such pixels are shone through by the light of an LED - indicated at the bottom in Fig. 9d. Additionally, as shown on the left in Fig. 9d - the pixels of different layers may partly or completely overlap.

If the light colour of the LED is blue for example and for example mixtures 233a and 233b are present, of which one changes the blue light to green and the other the blue to red, with a fineness of the pixel suitable to the observation distance for the observer, one may produce standing and not dynamically changing coloured pictures with an almost infinite variety of colours.

The necessary resolution of the pixels may indeed be manufactured by way of screen-printing-like method for such films which are to be observed at distances from a few metres and more. For protective films which are to be observed from small distances, one possibility for example is to firstly deposit the dyes in a layered manner firstly over the whole surface, and to subsequently photo-lithographically produce the necessary fine pixel structures.

Figure 10 shows a protective film constructed in principle according to Fig. 7a, which additionally to the optical function of light colour conversion or light colouring filtering, fulfils the optical function of diffuse light scattering. The film may of course in principle also be constructed according to any of the Figures 1a to 4d.

In the shown case and in all conceivable cases, a further layer 254 is present additionally to the other construction of the protective film. Although this layer 254 should produce diffuse light, it advantageously consists of one of the previously discussed permanently highly transparent, long-term stable plastics such as FEP or silicone. This is because the films which become dull, although not producing diffuse light, mainly however absorb light. Light absorption in our case however is completely undesired.

Diffuse light with as low as possible absorption may be produced by way of filling the highly transparent plastic 254 for example with metallic bodies 255 which mirror the light as completely as possible or for example with transparent hollow bodies 255, thus for example hollow glass balls, which partly let through the light and partly mirror it.

For the manufacture of such a layer filled for example with hollow glass balls, dissolved amorphous Teflon AF or highly viscous silicone is inter-mixed with hollow glass balls available on the market, subsequently deposited onto the otherwise finished protective film for example by way of doctoring, and then cured.

The previously described embodiments are mere examples as to how the invention may be implemented. A multitude of other possibilities also exists.

This application is based on the priority of the three Swiss patent applications 664/04, 1425/04 and 1957/04 whose contents is a constituent of this application and is herein taken up in this application by reference.